## §1. MSE Spectroscopy with Small Divergence Diagnosing Neutral Beam

Ida, K., Takayama, S., Nishimura, S.,
Kojima, M. and CHS group

$H_\alpha$ lines emitted from the high energy atomic hydrogen beam injected into a tokamak plasma have a polarization due to the Motional Stark Effect. A strong Lorentz field, $E = v_b \times B_t$, ( $v_b$ : neutral beam velocity $B_t$ : tokamak toroidal field) observed in the reference frame of the beam particle produces splitting and polarization of line emissions via the Stark effect. When observed in the direction perpendicular to the electric field, the Stark $\sigma$ and $\pi$ component are linearly polarized, respectively perpendicular and parallel to the direction of the Lorentz field. The polarization angle of $H_\alpha$ spectrum with Motional Stark Effect (MSE) emitted from the fast hydrogen ions of a neutral beam was measured through four linear polarizers tilted by 0, 45, 90, 135 degrees with respect to the toroidal magnetic field direction in front of the input optical fibers in the JIPP TII-U tokamak plasma. However, the non-uniformity of transmission of each fiber arrays produced non-negligible uncertainty and/or the offset of polarization angle. New polarization sensitive spectroscopy system has been developed to solve this problem and is now installed in CHS. This system consists of two sets of Ferroelectric Liquid Crystals (FLC), linear polarizers and object lense in front of the input optical fiber array. The two sets of 24-channel 132μm diameter optical fibers (106 μm core) are led into the entrance slit of a 0.5 m Czerny-Turner spectrograph with the space of 132 μm.

The optic axis of the FLC layer has two preferred orientations which are separated from each other by approximately 45 degree. FLC devices are bistable, electrically switchable wave plates. The FLC layer functions as a half-wave plate with a retardance of $\pi$. By applying a positive or negative voltage to the transparent electrodes, one of two sate (0 or $\pi$ retardance) will be selected. As shown in Figure 1, the linear polarizers are tilted by 45, 90 degrees with respect to the toroidal magnetic field direction. A two dimensional cooled DigDag CCD detector is located at the exit plane of the spectrometer. A ±5V DC balanced waveform (e.g. a 10 V peak to peak square wave) modulates the polarization angle between 0 and 90 degree or 45 and 135 degree.

Synchronized with the FLC modulation, charge of each CCD pixel can be shifted up and down (DigDag) by 6 pixels (132 μm) within 18 μs until the end of integration period, then all pixels will be read (readout time is typically 20 - 50 ms). The DigDag CCD will give the image of 96 spectra with the polarization angle of 0, 45 90, and 135 degree (24 spectra each). Since the total intensity of 0 and 90 polarization angle is identical to that of 45 and 135 degree, the difference of transmission of two sets of fiber arrays can be calibrated. The 96 spectra at 24 viewing chords and with four different polarization angles can be measured simultaneously. The spectra with the polarized angle of 0 and 90 degrees mainly give $\sigma$ and $\pi$ components of MSE spectrum and the difference of the spectra with the polarized angle of 45 and 135 degree gives the magnetic field pitch angle.

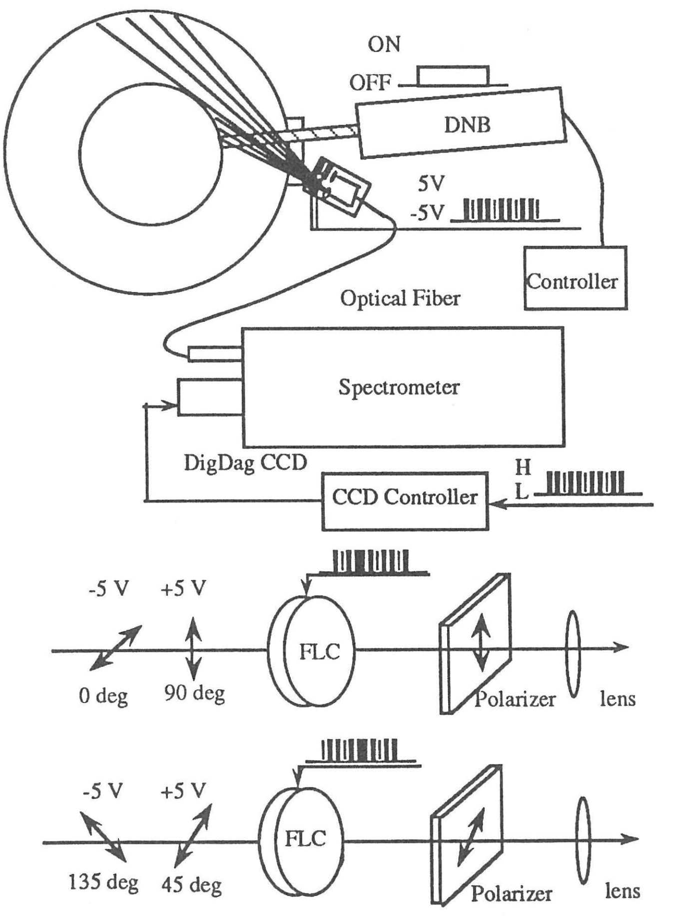


Fig.1.Schematic of charge exchange spectroscopy using FLC layer and DigDag CCD.